Fiber Optic Strain Gage Use on PE, Protocol Development

JR 3/17/09

Program Outline:

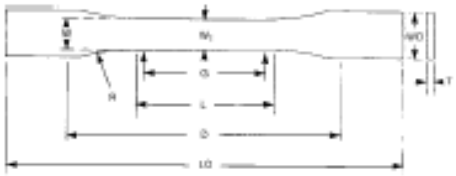
1) **Phase 1:** Goal: Characterize X3 PE Material properties in various loading conditions using uniaxial fiber optic strain gages and resistance based strain gages. Physical testing and predictive analysis will be used to gain greater insight into the complexities and limitations of the use of these tools. As part of this effort the following areas of evaluation will be considered:

    a. **<u>Physical Testing</u>**
    Conduct physical testing on X3 PE to establish the performance of fiber optic and resistance based gages in tension, compression and bending. Separate sample types will be used for each type of applied load. Principle strain and transverse strain will be recovered on a total of 5 samples for each condition for a total of 30 samples.
        i. Outputs
            1. Load vs gross deflection for quasi-static load to failure for each sample type.
            2. Useful principle strain limits for each gage type
            3. Useful transverse strain limits for each gage type
            4. True stress – strain curves for each loading condition for each sensor type
            5. Poissions ratio vs strain level for each loading condition for each sensor type
            6. Comparison of developed curves to supplied tensile curves
            7. Mounting specifics for each gage type
        ii. Inputs:
            1. Instron test equipment (Los Alamos)
            2. Resistance strain gage instruments, 2 channel (Los Alamos)
            3. Samples (Stryker)
            4. Fixtures (Stryker)
            5. Glue/ FO and Resistance Strain Gages (Stryker)
            6. Instrumentation (Mike T/ Los Alamos)
            7. True stress strain curve X3 (Stryker)
            8. Protocol (Stryker)

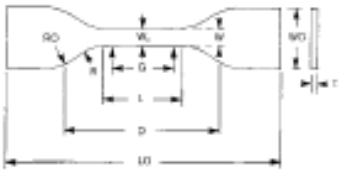
Test Setup (Tension)

Test to be run in accordance with ASTM D638-08 using Type I, sample, 6.35mm (0.25inch) thick, 165mm (6.5inch) long as shown in Figure 1. Test will be run at 2.0mm/ minute (0.079in/ minute) load application rate. Estimate approx 2000N required to reach yield (use 5kN load cell). Sample grips are shown in Figures 2A and 2B.

D 638 – 08



TYPES I, II, III & V



TYPE IV

Specimen Dimensions for Thickness, *T*, mm (in.)[A]

Dimensions (see drawings)	7 (0.28) or under		Over 7 to 14 (0.28 to 0.55), incl	4 (0.16) or under		Tolerances
	Type I	Type II	Type III	Type IV[B]	Type V[C,D]	
W—Width of narrow section[E,F]	13 (0.50)	6 (0.25)	19 (0.75)	6 (0.25)	3.18 (0.125)	±0.5 (±0.02)[B,C]
L—Length of narrow section	57 (2.25)	57 (2.25)	57 (2.25)	33 (1.30)	9.53 (0.375)	±0.5 (±0.02)[F]
WO—Width overall, min[G]	19 (0.75)	19 (0.75)	29 (1.13)	19 (0.75)	...	+ 6.4 (+ 0.25)
WO—Width overall, min[G]	...	...	...	...	9.53 (0.375)	+ 3.18 (+ 0.125)
LO—Length overall, min[H]	165 (6.5)	183 (7.2)	246 (9.7)	115 (4.5)	63.5 (2.5)	no max (no max)
G—Gage length[I]	50 (2.00)	50 (2.00)	50 (2.00)	...	7.62 (0.300)	±0.25 (±0.010)[C]
G—Gage length[I]	...	...	...	25 (1.00)	...	±0.13 (±0.005)
D—Distance between grips	115 (4.5)	135 (5.3)	115 (4.5)	65 (2.5)[J]	25.4 (1.0)	±5 (±0.2)

Figure 1: Tensile test sample dimensions

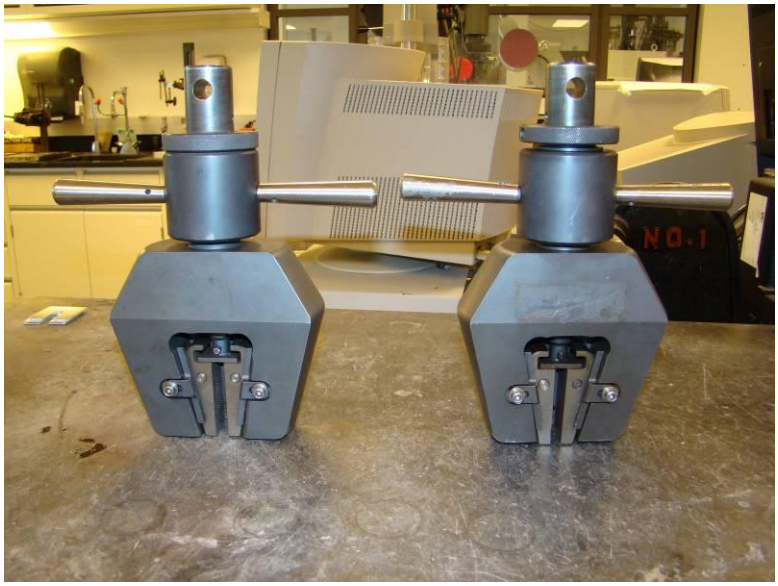


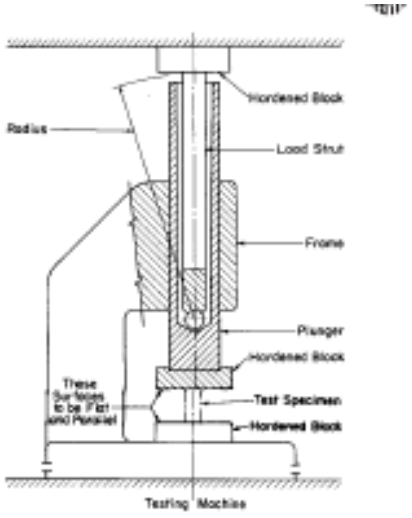
Figure 2A: Instron Tensile Sample Grips

Figure 2B: Instron Tensile Setup

Test Setup Compression

Test to be run in accordance with ASTM D 695-08 with noted changes due to use of PE material. A cylindrical sample of ample length will be used to minimize the effect of barreling of the sample due to end condition friction. A 12.7mm (0.5 inch) diameter cylindrical sample, 50.8mm (2.0inch) long will be used. Test will be run at 1.3mm/ minute (0.05 in/ min). Estimate approx 5000N required to reach 40MPa (use 10kN load cell). An example of a compression test platen is shown in Figure 3 and a schematic of an ASTM D695 compression test fixture is shown in Figure 3A.

Figure 3: Instron Compression Test Platen



Note 1—Devices similar to the one illustrated have been successfully used in a number of different laboratories. Details of the device developed at the National Institute for Standards and Technology are given in the paper by Aitchinson, C. S., and Miller, J. A., "A Subpress for Compressive Tests," National Advisory Committee for Aeronautics, Technical Note No. 912, 1943.

Figure 3a: ASTM D695 compression test fixture

Test Setup Bending (4 Pt Bend)

Test to be run in accordance with ASTM D790, as modified in detailed protocol to accommodate PE material characteristics. A rectangular sample will be used 12.7mm (0.5 inch) deep, 25.4mm (1.0 inch) wide and 203.2mm (8inches) long. Support span setting is 152.4 mm(6 in). Load application span setting TBD and load required are expected to be within the 5 to 10 kN range. Four Point bend Instron Test Fixturing is shown in Figure 4.

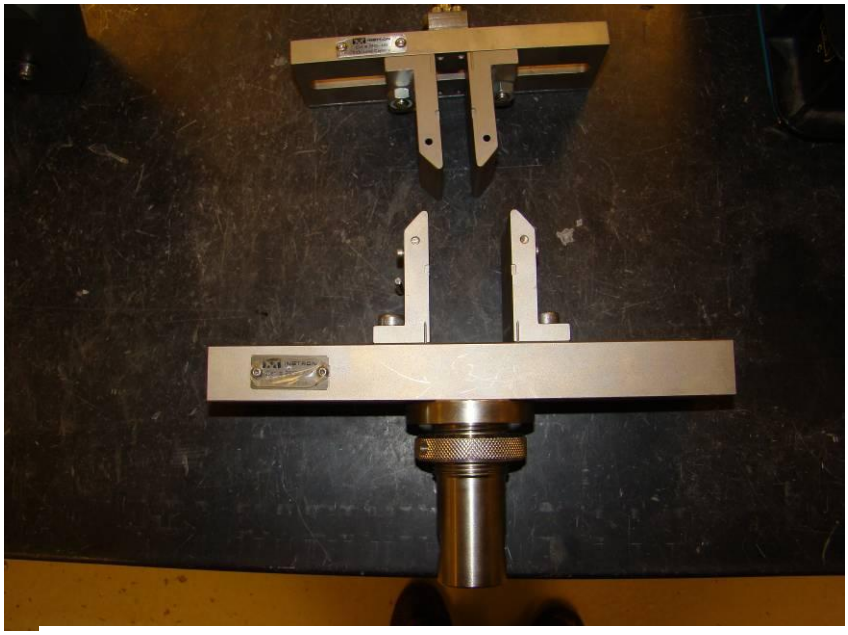


Figure 4: Four Point bend Instron Test Fixturing

b. Predictive Analysis

Conduct finite element analysis on each X3 PE sample type subject to loading in accordance with physical test efforts. Using measured material properties and various material models to predict the strain gage recovered and cross head recovered response for each sample type.

i. Outputs
   1. Load specific FE Models
   2. Predicted strain gage response strain for each material model considered for each loading type (Linear, Small Displacement)
   3. Predicted cross head response for each material model considered for each loading type (Non Linear, Large displacement)
   4. Refined tension, compression and bending material models for linear and non-linear predictions.

ii. Inputs
    1. CAD Models for each sample type (Stryker)
    2. FE Code (Los Alamos)
    3. Material model selection guidance (Los Alamos)
    4. Model development guidance (Los Alamos)
    5. Linear/ Non-linear large displacement model guidance (Los Alamos)

Phase 2: Goal: Characterize the PE liner peripheral face strain field in multiple orthopaedic acetabular shell constructs under physiological loading. Physical testing will be used to evaluate the effect of PE thickness on the hoop strain field of the liner face at various inclination angles and head offsets.

a. <u>Physical Testing</u>

Conduct physical testing on X3 PE liners of various thickness at multiple inclination angles and head offsets. A model of a 56F Trident, 44 mm head at 60 deg inclination to be used in Phase 2 is shown in Figure 5. Circumferential strains as close to the ID and at various (need to define) radial distances from the ID will be recovered on a total of 3 PE liner samples. A total of 3 inclination angles with a total of 3 head subluxation offsets of 0, 1 and 2 mm at each inclination angle will also be considered for each sample

iii. Outputs
    1. Strain vs load vs inclination vs thickness vs offset for each sample type (vs radial location?).
    2. Comparison of recovered strain to measured values from physical test (yield ultimate etc)

iv. Inputs:
    1. Instron test equipment (Los Alamos)
    2. Load applicator (Stryker)
    3. Samples (Stryker)
    4. Test Fixtures (Stryker)
    5. FO Strain Gages (Stryker)
    6. Instrumentation (Mike T)
    7. Protocol (Stryker)

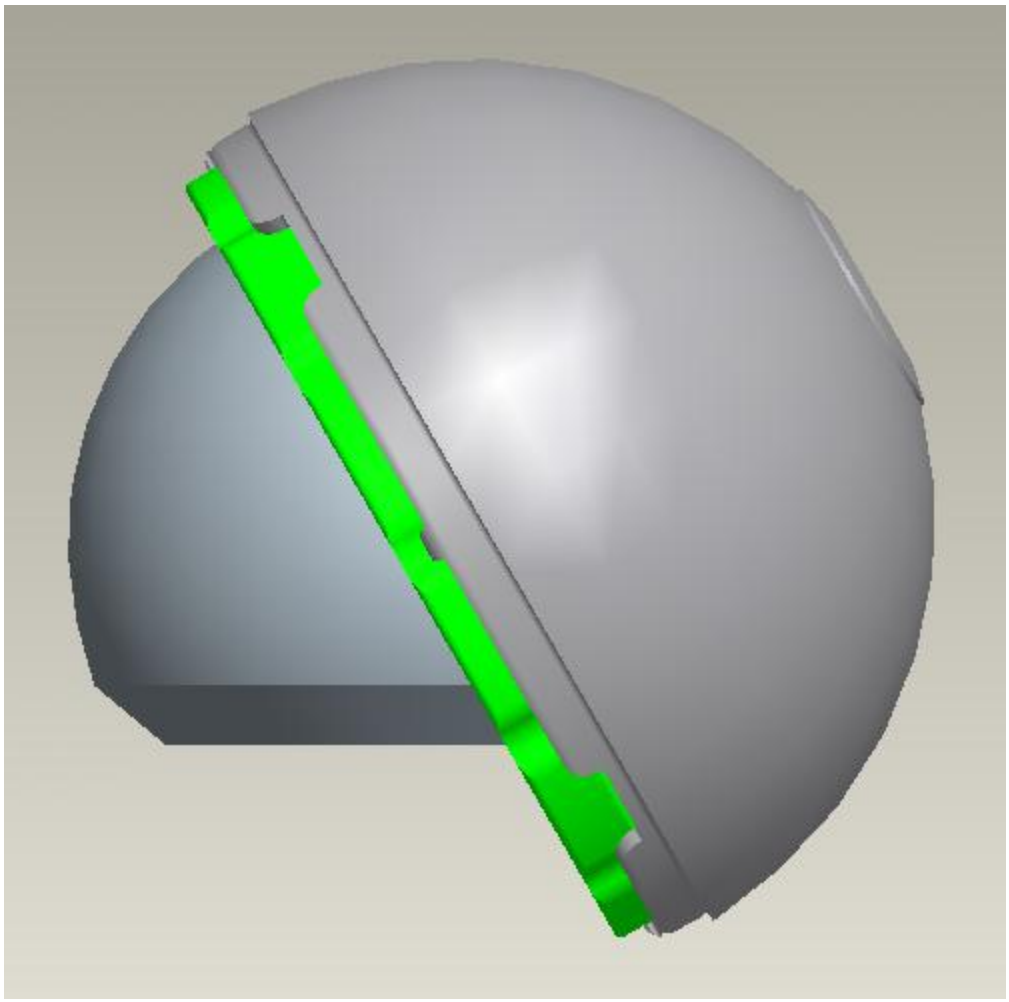
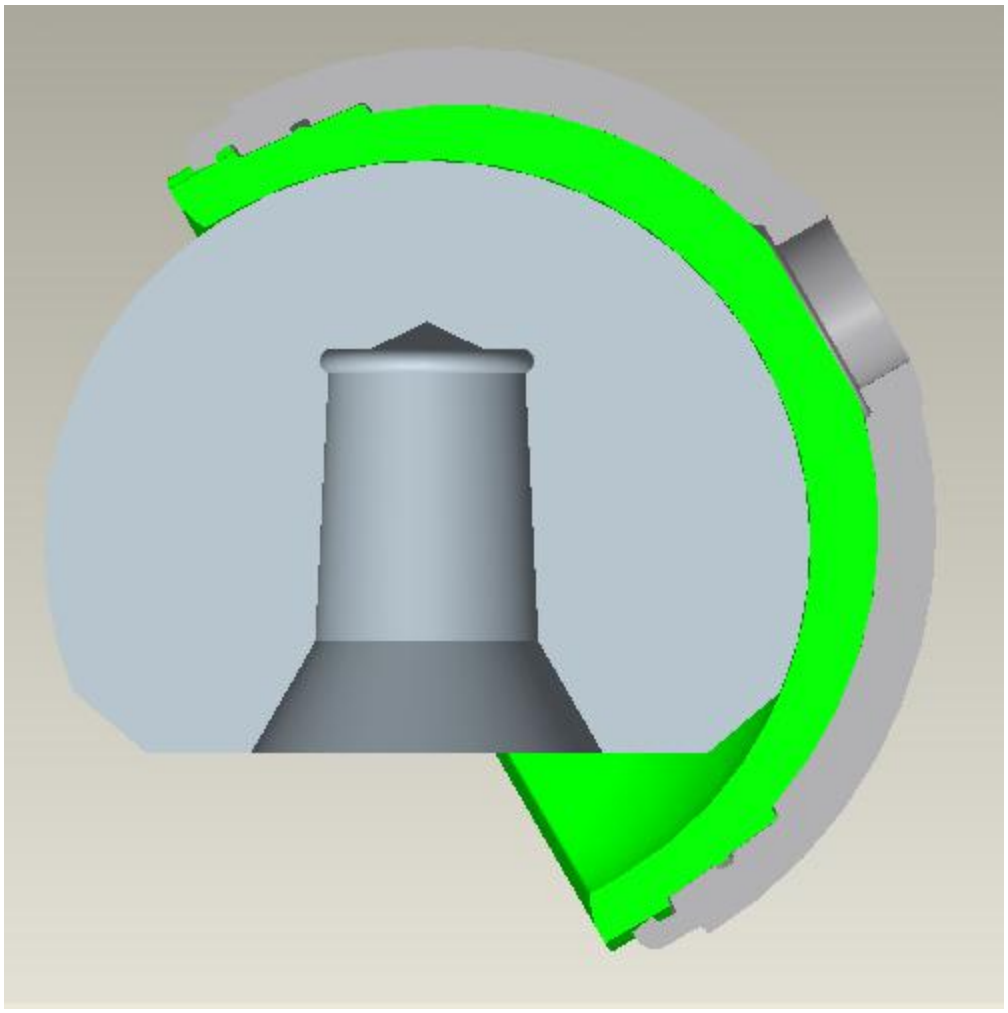


Figure 5: 56F Trident, 44 mm head at 60 deg inclination to be used in Phase 2.



Phase 2, Figure 2: 56F Trident, 44 mm head at 60 deg inclination